
Acute Care

Nurse Staffing and Postsurgical Adverse Events: An Analysis of Administrative Data from a Sample of U.S. Hospitals, 1990–1996

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Objective. To examine the impact of nurse staffing on selected adverse events hypothesized to be sensitive to nursing care between 1990 and 1996, after controlling for hospital characteristics.

Data Sources/Study Setting. The yearly cross-sectional samples of hospital discharges for states participating in the National Inpatient Sample (NIS) from 1990–1996 were combined to form the analytic sample. Six states were included for 1990–1992, four states were added for the period 1993–1994, and three additional states were added in 1995–1996.

Study Design. The study design was cross-sectional descriptive.

Data Collection/Extraction Methods. Data for patients aged 18 years and older who were discharged between 1990 and 1996 were used to create hospital-level adverse event indicators. Hospital-level adverse event data were defined by quality indicators developed by the Health Care Utilization Project (HCUP). These data were matched to American Hospital Association (AHA) data on community hospital characteristics, including registered nurse (RN) and licensed practical/vocational nurse (LPN) staffing hours, to examine the relationship between nurse staffing and four postsurgical adverse events: venous thrombosis/pulmonary embolism, pulmonary compromise after surgery, urinary tract infection, and pneumonia. Multivariate modeling using Poisson regression techniques was used.

Principal Findings. An inverse relationship was found between RN hours per adjusted inpatient day and pneumonia ($p < .05$) for routine and emergency patient admissions.

Conclusions. The inverse relationship between pneumonia and nurse staffing are consistent with previous findings in the literature. The results provide additional evidence for health policy makers to consider when making decisions about required staffing levels to minimize adverse events.

Key Words. Registered nurse, staffing, adverse events, outcomes

BACKGROUND AND SIGNIFICANCE

Concerns of inadequate nurse staffing in hospitals and its potential adverse impacts on quality of care have been expressed recently in both the popular press (Appleby 1999; Berens 2000) and in the professional literature (Aiken et al. 1999; Blegen, Goode, and Reed 1998; Buerhaus and Needleman, 2000; Fridkin et al. 1996; Kovner and Gergen 1998; Kovner, Jones, and Gergen 2000; Pronovost et al. 1999; Schultz et al. 1998; Wunderlich, Sloan, and Davis 1996). These concerns come primarily from two sources. First, the effects of changes in nurse staffing levels that resulted from restructuring and reengineering efforts occurring in health-care organizations over the past decade are largely unknown (Walston, Burns, and Kimberly 2000). Second, the nation is currently faced with reports of a severe shortage of registered nurses (Kilborn 1999), an aging nurse workforce (Buerhaus, Staiger, and Auerbach 2000), and declining nursing school enrollments (American Association of Colleges of Nursing 2000; Carpenter 2000; U.S. Department of Labor 2000). The landmark Institute of Medicine (IOM) study (Wunderlich, Sloan, and Davis 1996) explored the relationship between nurse staffing and quality of care in hospitals and nursing homes, only to determine that insufficient data were available to adequately address the issue.

Such concerns are critical issues for acute-care hospitals, where RN wages represent a large portion of labor costs (Hospital Statistics 2000). As a result, the RN workforce is often a target for cutbacks (Spetz 1998). To understand the

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effects of changes in nurse staffing, we need to understand the relationship between nurse staffing and patient outcomes. Although this relationship has been discussed theoretically (American Nurses Association 1995; Johnson and Maas 1997; LaBelle 1993; Lewin-VHI 1995; Maas, Johnson, and Moorhead 1996; Pierce 1997), there is little empirical evidence upon which to base nurse staffing decisions. Moreover, results reported in the literature are often contradictory. For example, prior research has documented an inverse relationship between nurse staffing and mortality (Hartz et al. 1989; Krakauer et al. 1992; Manheim et al. 1992; Prescott 1993; Silber, Rosenbaum, and Ross 1995; Wunderlich, Sloan, and Davis 1996), but the relationship between nurse staffing and some nonfatal adverse events is unclear (Aiken, Smith, and Lake 1994; Grillo-Peck and Risner 1995). Still other efforts have reported an inverse relationship between nurse staffing and nosocomial infections (Blegen and Vaughn 1998; Flood and Diers 1988; Fridkin et al. 1996; Kovner and Gergen 1998; Lichtig, Knauf, and Milholland 1999), which contradicts reports of no relationship between nurse staffing and infections (Iezzoni et al. 1994; Shortell et al. 1994; Taunton et al. 1994) or other complications (Lipsett and Bass 1999; Silber et al. 1995).

Among the reasons for different study findings are different samples, nonuniformity of data collection methods, a wide variety of outcome and staffing measures, and possibly nonlinear relationships. This study is a large representative sample using consistent data collection methods and, therefore, has more generalizability than previous studies.

The lack of evidence on nurse staffing levels that meets both quality and cost imperatives presents a challenge to policymakers and managers in hospitals. In spite of minimal research in this area, California enacted legislation in 1999 to mandate registered nurse-to-patient ratios in acute-care hospitals (Purdum 1999; Rundle 1999). Under this legislation, California's Department of Health Services must define and enforce RN-to-patient ratios by 2002 (Spetz et al. 2000). Some are concerned that this mandate may produce increased hospital costs (Spetz 2001) or produce results opposite to its intention (Buerhaus 1997; Kovner 2000). That is, hospitals with high nurse staffing levels actually may decrease staffing to a lower mandated level that may be inadequate and compromise quality of care, while hospitals with low staffing levels may raise staffing levels to meet the mandate, yet this increase may still be insufficient to bring about intended increases in quality.

The study reported here examines nurse staffing levels in a sample of U.S. short-term, general hospitals from 1990 to 1996, and relates those levels to four adverse events found previously to be sensitive to nursing care (Kovner and

Gergen 1998). In an effort to improve upon previous work in the area, primarily by better controlling for severity of illness, results of this study will add to the growing body of evidence on the relationship between nurse staffing and patient outcomes. Further, this study will provide information to enable clinicians, researchers, administrators, and policymakers to highlight the consequences of modifying RN staffing levels on the quality of patient care.

SAMPLE

Data for this study were taken from two sources: Nurse staffing data from 1990–1996 were obtained from the American Hospital Association (AHA) annual Survey of Hospitals; adverse event data were obtained from the National Inpatient Sample (NIS) for the same seven-year period. NIS is part of the Healthcare Cost and Utilization Project (HCUP) at the Agency for Healthcare Research and Quality (AHRQ). This database contains all hospital discharge claims from a 20 percent stratified, probability sample of nonfederal U.S. community hospitals collected annually (Ball et al. 1995). The database includes demographic, diagnostic, and treatment information for each discharged patient. Comorbidity, diagnosis, and procedures are coded using ICD-9-CM, DRG, and Major Diagnosis Codes. The NIS includes data about hospitals, and a cross-walk file that allows researchers to link NIS data to AHA data from which more explicit hospital characteristics can be obtained (General Information for HCUP-3 Nationwide Inpatient Sample, Release 2, 1996).

METHODS

The Quality Indicators (QIs) software developed by Healthcare Cost and Utilization Project-3 (HCUP-3) at AHRQ was used to identify adverse events and corresponding risk population (i.e., denominators) for calculating hospital-level adverse events rates (Ball et al. 1995; Johantgen et al. 1998). The software screens and flags, discharge by discharge, predefined adverse events using ICD-9-CM codes and applies predetermined exclusion and inclusion criteria to identify discharges for which adverse events could occur. The HCUP QIs include 33 different rates. Table 1 shows the definition of the four QIs and exclusion criteria for the population at risk that were used in this study. These were chosen because in a single year study they were significant. Specific ICD-9 codes that were included can be found elsewhere (Ball et al. 1995). To further

Table 1: Definition of Adverse Event and Risk Population

<i>Quality Indicator: (Num./Den.)*100</i>	<i>Adverse Event: Numerator</i>	<i>Population at Risk: Denominator</i>
Venous thrombosis or pulmonary embolism after major surgery	Postoperative discharges with venous thrombosis or pulmonary embolism in any secondary diagnosis	All nonmaternal/non-neonatal discharges age 18 or older with major surgery procedure on day 1 or 2 of admission
Pulmonary compromise after major surgery	Postoperative discharges with pulmonary congestion, lung edema, or respiratory insufficiency or failure in any secondary diagnosis	All nonmaternal/non-neonatal discharges age 18 or older with major surgery on day 1 or 2 of admission
Urinary tract infection after major surgery	Postoperative discharges with urinary tract infection in any secondary diagnosis	All nonmaternal/non-neonatal discharges age 18 or older with major surgery on day 1 or 2 of admission
Pneumonia after major surgery	Postoperative discharges with pneumonia in any secondary diagnosis	All nonmaternal/non-neonatal discharges age 18 or older with major surgery procedure on day 1 or 2 of admission

limit variation in severity, we limited patients to those who were admitted from the emergency room or as planned admissions, thus eliminating patients admitted from nursing homes, other hospitals, and elsewhere. The QIs were calculated only for hospitals where the denominators were greater than or equal to 30 following the recommendation of HCUP-3.

Hospital staffing variables were created from the AHA database. Nurse staffing was measured as the number of full-time-equivalent (FTE) registered nurses (RNs) and licensed practical nurses (LPNs) working in the hospital and outpatient department per adjusted patient day. The AHA survey does not require that hospitals differentiate between employees working in outpatient and inpatient settings. Instead, hospitals only report overall staffing. The AHA's adjusted patient day is a conversion of outpatient visits to inpatient days based on the ratio of outpatient to inpatient charges. By using the ratio of RNs to adjusted patient day, hospitals with large outpatient departments do not appear to have higher staffing levels than those facilities without outpatient departments. Other staffing variables included were physician and dentist, and resident and intern. The AHA combines physician and dentist data. The FTEs were converted to hours by multiplying one FTE by 2,040 hours, except for residents and interns. Because interns and residents work substantially more than 40 hours per week we multiplied their FTE by 3,120 (<http://www.ama-assn.org/scipubs/amnews/pick-01/prsa0521.htm>). Thus, we report hours *paid*, not hours worked.

Other hospital characteristics, including hospital bed size, location, region, ownership, teaching status (membership in the Council of Teaching Hospitals [COTH]), hospital affiliation with HMO or PPO (yes or no), and hospital-owned nursing school (yes or no), were retrieved from the AHA database and merged with hospital-level QIs. Ownership was defined as government, private not-for-profit, and private investor-owned.

It is conceivable that postsurgical complications are more likely to occur in patients with severe conditions. To control for the confounding effects of case mix, we included the Medicare Case-Mix Index (CMI) for each year, proportion of patients for whom Medicare was the principal payer, proportion of patients for whom Medicaid was the principal payer, and source of admission in our analysis. None of these measures is a sufficient measure of case mix, but together they are likely to capture the difference in severity across hospitals.¹ In addition, we included a year-specific, fixed-effect in our regression analysis as an additional control for the case mix effect that may have occurred during the study period.

Sample

It was necessary to exclude some states and hospitals from some states included in the NIS for the following reasons: (1) the state did not require hospitals to report the day on which the principal procedure was performed as part of discharge data which was necessary for the QI calculation; (2) the state did not permit linking of NIS data to the AHA database; (3) hospitals were not in operation for a full calendar year; and/or, (4) hospitals were exclusively children's hospitals. The final sample included hospitals from six states for the years 1990–1992; four additional states for a total of ten states in the years 1993–1994; and three more states for a total of thirteen states between the years 1995–1996.

The analytical sample includes 530–570 hospitals for each of the years from 1990–1996, with 187 hospitals having data for all seven years. Hospitals from Florida account for 26.4 percent of the pooled sample, Wisconsin 16.8 percent, California 15.2 percent, Pennsylvania 11.3 percent, Massachusetts 5.8 percent, and New Jersey 4.3 percent. Hospitals from Connecticut, Iowa, Maryland, and New York were included in the sample from 1993, when these states started contributing data to NIS. These four states account for 0.8 percent, 6.2 percent, 4.1 percent, and 5.3 percent of the analytical sample respectively. Hospitals from Missouri, Oregon, and Arizona were added to the sample from 1994–1996, accounting for 2.4 percent, 0.8 percent, and 0.6 percent of the sample respectively. These data are not representative of all U.S. states; the data do provide geographic diversity.

STATISTICAL ANALYSES

Trends in four QIs over the seven-year study period were described and correlated to nurse staffing. Regression analyses were used to identify the independent effect of nurse staffing variables on QIs, recognizing the correlation between the staffing variables and other predictors of hospital QIs.

QI events are small, discrete, and nonnegative counts, therefore our analyses assume that the number of QI events in hospitals is a Poisson-distributed random variable with Poisson parameter, λ_i (Burgess et al. 2000; Christiansen and Morris 1996, 1997; Luft and Brown 1993; Ulm 1990). The logarithm of the expected count of QI events is modeled here as a linear function of explanatory variables, so that

$$\log E(Y_{it}|\lambda_i) = \lambda_i + X_{it}B + T_t\Gamma + \log(P_{it})$$

where λ represents the expected number of QI events in each hospital, B is a set of parameters for a set of covariates X_{it} , such as hospital size, ownership, and other characteristics, and, of critical interest to this study, nurse staffing levels. The B is assumed to be constant across hospitals (denoted by i). The T denotes time-invariant factors represented by a set of year-specific dummy variables for each year between 1990 and 1996. Γ is a set of coefficients for T . The P denotes the population at risk over which the number of adverse events, Y , is observed. The subscripts i and t refers to hospital i and year t .

Our model deviates from a standard Poisson model in several ways. First, it captures patient-level predictors of a QI in a set of variables that measure the severity of case mix at the hospital-level, including source of admission, Medicare case mix, and percentage of patients covered by Medicare and Medicaid. Second, we account for the different exposure by including an offset factor, the natural log of the population at risk, in the log-linear model and its coefficient is forced to be 1. Although the Poisson distribution is often used to model count data, one of the assumptions of this distribution, mean of y = variance of y , is rarely met. Overdispersion is observed in the data as expected, signaled by a variance-to-mean ratio greater than 1. We adopted a commonly used model for overdispersion, the negative binomial model distribution, which assumes that given a rate λ_i , Y_{it} are independent Poisson variates with mean and variance equal to λ_i (Diggle, Liang, and Zeger 1995), as indicated by our regression equation.

The cross-sectional and time series data allow estimation of the effects of nurse staffing on adverse events based on time-wise variation within hospitals, as well as variation across hospitals. Because there is relatively smaller within-hospital variation than cross-hospital variation in the QIs and nurse staffing and also because the data set contained only a few years of data, the benefit of having a time-series could not be fully realized (that is, the association of changes in staffing level and changes in QIs can not be studied). However, the analysis benefits from the increase in statistical power derived from a bigger sample size rather than a single-year cross-sectional analysis. This augmentation of power may be critical in our analyses because nurse staffing levels are expected to explain only a portion of patient outcomes and the hypothesized association could be easily muffled by random variation and other more significant confounding factors. The generalized estimating equation (GEE) approach (Diggle, Liang, and Zeger 1995) was used to adjust for correlation of QIs within hospitals. Standard errors were estimated using Huber/White/sandwich estimator in case the correlation within hospitals was not as

hypothesized by the model. The estimation was carried out in STATA version 6 (Stata Corporation 1999).

RESULTS

Characteristics of the hospital sample are presented in Table 2. The mean bed size ranged from 206 in 1990 to 180 in 1996. The distributions of hospitals by region, ownership, teaching and nursing school affiliation were similar over the seven-year period, while higher percentages of rural hospitals and public hospitals are represented in the sample in later years. The case mix index showed a small but steady increase, as did the percentage of patients covered by Medicare and Medicaid and the percentage of hospitals affiliated with HMOs and PPOs. Such increases may suggest higher acuity in the nation's short-term general hospitals, driven by the expansion of managed care (Prospective Payment Assessment Commission 1997; Spetz 1998).

Table 3 presents the distribution of nurse staffing and the four QIs for the years 1990 to 1996. The RN, physician, and resident intern hours per adjusted patient day had a steady increase during the study period, while LPN hours per adjusted patient day steadily declined. All of the four adverse event rates showed a steady increase between 1990 to 1997, with the exception of urinary tract infection (UTI) rates, which remained relatively constant over the period. However, for all years, rates of UTI are higher than the other three adverse event rates.

The parallel increases in RNs and QIs suggest a positive, rather than an inverse, relationship between nurse staffing and the QIs. Since there was a steady increase in case mix and a positive association between adverse events and QIs, as confirmed by bivariate analysis², the relationship should be assessed while controlling for case mix and other confounding factors. It should also be noted that only 187 hospitals remained in the sample for the entire seven-year period, and consequently, the increase or decrease observed may be all or partially due to differences in the set of hospitals in each year's sample. The independent effect of nurse staffing was therefore analyzed by regressions, shown in Table 4. As discussed previously, estimates reported here were from negative binomial regressions with the pooled seven-year data, and the standard errors (SE) were adjusted for time-wise correlation within hospitals across years.

Table 4 shows that after controlling for other variables RN hours per adjusted patient day were inversely related to all adverse events, but was significant ($p < .05$) only for pneumonia. The LPN hours per adjusted patient

Table 2: Characteristics of Hospitals in the Analytical Sample

Characteristics	1990	1991	1992	1993	1994	1995	1996
Number of Hospitals	549	528	530	570	547	560	534
Number of Beds (Mean [sd])	206(182)	203(177)	205(179)	196(196)	197(194)	178(181)	180(189)
Rural Hospitals (%)	25.5	24.8	25.3	30.2	29.4	33.6	33.5
Ownership							
Public (%)	12.4	11.2	10.4	17.0	16.5	17.3	17.2
Voluntary (%)	72.1	74.2	75.1	69.6	72.4	70.5	71.0
Proprietary (%)	15.5	14.6	14.5	13.3	11.2	12.1	11.8
Census Region							
North East (%)	29.1	29.0	30.6	27.4	28.2	25.2	23.0
North Central (%)	20.2	19.9	20.0	25.8	28.0	32.0	31.5
South (%)	32.6	33.1	31.1	33.2	30.3	26.3	27.0
West (%)	18.0	18.0	18.3	13.7	13.5	16.6	18.5
Nursing School Affiliated (%)	4.6	3.8	4.0	2.8	3.5	3.8	4.1
Managed Care Affiliation							
HMO Affiliated (%)	69.8	72.5	72.1	71.6	61.4	77.9	80.5
PPO Affiliated (%)	67.6	71.6	71.9	69.1	62.9	79.6	82.0
Medicare Case Mix Index (mean [sd])	1.27(0.20)	1.30(0.22)	1.31(0.24)	1.30(0.24)	1.31(0.24)	1.32(0.25)	1.33(0.26)
Percentage Medicare (mean [sd])	43.4(13.8)	44.3(14.3)	46.1(14.8)	47.1(14.8)	47.2(14.8)	48.6(14.9)	49.0(15.0)
Percentage Medicaid (mean [sd])	9.4(9.6)	9.4(9.6)	11.2(10.6)	12.1(10.8)	12.0(11.0)	11.9(10.0)	11.9(10.8)

Table 3: Distribution of Staffing Levels per Patient Day and QIs per 100 Surgical Patients Discharged from 1990 to 1996

<i>Nurse Staffing and QI</i>	<i>1990</i>	<i>1991</i>	<i>1992</i>	<i>1993</i>	<i>1994</i>	<i>1995</i>	<i>1996</i>
RN Hours per Adjusted Patient Day							
Mean	5.84	6.01	5.90	6.13	6.13	6.39	6.56
Median	5.69	5.77	5.90	5.95	6.12	6.31	6.43
25th Percentile	4.35	4.42	4.31	4.52	4.51	4.44	4.69
75th Percentile	7.04	7.20	7.25	7.37	7.67	8.03	8.11
LPN Hours per Adjusted Patient Day							
Mean	1.24	1.23	1.13	1.09	1.01	1.01	0.97
Median	1.11	1.13	1.03	0.87	0.77	0.80	0.77
25th Percentile	0.64	0.62	0.58	0.47	0.43	0.42	0.41
75th Percentile	1.67	1.63	1.53	1.39	1.32	1.36	1.36
MD/Dentist Hours per Adjusted Patient Day							
Mean	0.14	0.14	0.21	0.30	0.36	0.35	0.40
Median	0	0	0	0	0.05	0.08	0.10
25th Percentile	0	0	0	0	0	0	0
75th Percentile	0.14	0.13	0.19	0.22	0.33	0.38	0.48
Resident/Intern Hours per Adjusted Patient Day							
Mean	0.26	0.33	0.40	0.46	0.51	0.49	0.43
Median	0	0	0	0	0	0	0
25th Percentile	0	0	0	0	0	0	0
75th Percentile	0.025	0	0	0.10	0.25	0.08	0.07
Postoperative Venous Thrombosis/Pulmonary Embolism							
Mean	0.32	0.33	0.35	0.35	0.37	0.40	0.42
Median	0.26	0.27	0.31	0.27	0.31	0.31	0.32
25th Percentile	0	0	0.06	0	0	0	0.12
75th Percentile	0.45	0.46	0.48	0.53	0.51	0.56	0.59
Post-Operative Pulmonary Compromise							
Mean	0.62	0.65	0.72	0.81	0.80	0.95	1.00
Median	0.48	0.54	0.59	0.66	0.69	0.78	0.80
25th Percentile	0.22	0.25	0.27	0.31	0.32	0.39	0.36
75th Percentile	0.85	0.90	0.97	1.11	1.08	1.24	1.33
Post-Operative Pneumonia							
Mean	0.75	0.77	0.78	0.95	1.05	1.13	1.24
Median	0.53	0.55	0.70	0.78	0.86	0.92	0.95
25th Percentile	0.26	0.25	0.29	0.37	0.46	0.50	0.53
75th Percentile	0.92	0.94	1.08	1.26	1.36	1.55	1.59
Postoperative Urinary Tract Infection							
Mean	3.77	3.75	3.84	3.72	3.81	3.57	3.68
Median	3.17	3.20	3.21	3.07	3.21	2.99	3.00
25th Percentile	2.17	2.10	2.12	2.09	2.04	2.07	2.06
75th Percentile	4.75	4.62	4.94	4.74	4.89	4.47	4.65

Table 4: Regression Coefficients for Four Quality Indicators (beta[SE])

Explanatory Variable	Thrombosis	Pulmonary Compromise	Urinary Tract Infection	Pneumonia
RN Hours per Adjusted Patient Day	-.0002(.0082)	-.0047(.0074)	-.0064(.0055)	-.0169(.0077)*
LPN Hours per Adjusted Patient Day	-.0399(.0260)	.0023(.0221)	.0065(.0157)	-.0080(.0251)
MD/DDS Hours per Adj. Patient Day	-.0664(.0299)*	-.0116(.0270)	-.0325(.0192)	.0098(.0281)
Resident/Intern Hours per Adj Patient Day	.1004(.0294)**	.0382(.0168)*	.0009(.0114)	.0427(.0177)*
Number of Beds	.0004(.0001)**	.0003(.0001)*	-.0003(.0001)**	-.0001(.0001)
Location (urban = 1, rural = 0)	-.0015(.0711)	.3034(.0615)**	.0059(.0441)	.0380(.0600)
Ownership-public (reference: private hospital)	-.0397(.0942)	-.1724(.0934)	-.0588(.0642)	.0716(.0840)
Ownership-voluntary (reference: private hospital)	-.0389(.0821)	-.2395(.0673)**	-.2094(.0483)**	-.0935(.0703)
North East (reference = West)	.0173(.0722)	-.2679(.0685)**	.2436(.0484)**	-.1180(.0660)
North Central (reference = West)	.0708(.0786)	-.3804(.0792)**	.2839(.0536)**	-.0098(.0675)
South (reference = West)	.0095(.0741)	.1588(.0678)*	.4652(.0489)**	.0149(.0657)
Nursing School Affiliation	.1327(.0920)	-.1140(.0950)	-.0168(.0587)	-.1342(.0959)
Affiliated with HMO	.0237(.0475)	.0169(.0457)	-.0393(.0283)	-.0208(.0430)
Affiliated with PPO	-.0383(.0442)	.0129(.0439)	-.0171(.0273)	.0086(.0424)
Percent Medicaid Patients	-.0007(.0024)	.0099(.0025)**	.0075(.0018)**	.0130(.0024)**
Percent Medicare Patients	.0088(.0020)**	.0049(.0019)*	.0146(.0015)**	.0143(.0019)**
Medicare Case Mix Index	.1931(.1092)	.3044(.1063)**	.0160(.0755)	-.1448(.1034)
1991 Dummy (reference = 1990)	.0458(.0456)	.0056(.0384)	.0066(.0216)	.0444(.0388)
1992 Dummy (reference = 1990)	.1508(.0467)**	.1640(.0406)**	.0229(.0243)	.0717(.0436)
1993 Dummy (reference = 1990)	.1659(.0486)**	.2538(.0450)**	-.0786(.0269)**	.2289(.0471)**
1994 Dummy (reference = 1990)	.2521(.0494)**	.3326(.0486)**	-.0825(.0273)**	.3678(.0480)**
1995 Dummy (reference = 1990)	.3091(.0519)**	.4237(.0508)**	-.1426(.0322)**	.3880(.0485)**
1996 Dummy (reference = 1990)	.3116(.0559)**	.5341(.0537)**	-.1289(.0346)**	.4395(.0500)**
R-square ¹	0.05	0.19	0.24	0.09
N	3,581	3,581	3,573	3,580

1: R-square is from regressing QI on the list of explanatory variables, for illustration purpose (XTGEE module in Stata does not provide R-square or other overall measures of the model)

*p<.05

**p<.01

day was not significantly associated with any adverse events. Among the other staffing variables, resident/intern hours per adjusted patient day was positively ($p < .05$) related to all adverse rates except UTI. Hospital percentages of Medicare and Medicaid patients were also positively related to all adverse events except the relationship between percent of Medicaid patients and pulmonary thrombosis. The estimated coefficients for the set of year dummies show increased numbers of adverse events over the years that were not explained by included variables. Data from patients admitted from the ER were analyzed separately from routine patient admissions. Although patients admitted from the ER had higher levels of all adverse events, there were no differences in the relationships among variables; thus, we report only combined data.

DISCUSSION

While some individual hospitals may have decreased their numbers of RN staff, overall hospital staffing data from this sample of hospitals from 1990 to 1996 do not confirm anecdotal reports of declining RN staffing levels. Regression analyses provide some evidence to support an inverse relationship between RN staffing and hospital adverse events, with four post-operative adverse events being negatively associated with RN staffing levels, and one of which was statistically significant. Changes in RN staffing levels experienced over time were not sufficient to impact QIs. Although LPN hours did decrease, their hours were not consistently related to adverse events. In spite of this finding, it may be declining LPN hours during this period that have contributed to anecdotal reports of declining nurse staffing in general. That is, fewer LPN hours may place additional burdens on RN staff when LPNs are not available to provide patient care and to fill a supportive role in patient-care delivery (Aiken, Sochalski, and Anderson, 1996).

There are several study limitations that relate to the use of staffing data. A potential problem with the AHA data is that the data do not distinguish between direct care RNs and those RNs employed by the hospital in indirect or management roles. Unfortunately, if the increase in RN staffing was for RN managers this could blunt any impact of staffing increases on patient outcomes. Moreover, the AHA staffing data reflect paid hours and therefore likely overestimate productive hours. Another imitation is that the AHA data set does not include unlicensed assistive personnel.

Of interest in terms of staffing was the finding that resident intern hours were positively related to adverse events. This finding could reflect problems

that occur when residents rather than more experienced physicians are responsible for care. On the other hand, it could reflect that residents work in facilities with more severely ill patients and that this severity was not accounted for by the case-mix adjustments used in this study. Our findings on other hospital characteristics (e.g., ownership, size, location) are mixed, and therefore, consistent with earlier reports (Al-Haider and Wan 1991; Manheim et al. 1992; Lichtig, Knauf, and Milholland 1999; Shortell et al. 1994; Silber, Rosenbaum, and Ross 1995).

While the rate of adverse events increased over the time period studied, the increase in *QI* rates may be because of hospital upcoding rather than any real change in *QIs*. In other words, the relationship documented here may reflect coding changes rather than true changes in the underlying patient health. Quality is determined by many factors, one of which is nurse staffing. Our pooled sample increased the sample size by seven times, but, given the existence of many confounding factors and clustering within hospitals, our analysis may still suffer from lack of statistical power to identify the independent effect of nurse staffing. There is also a lack of understanding about how nurse staffing actually affects quality in general and how nurse staffing interacts with other factors, such as physician staffing, hospital beds, and so forth, in determining quality. That is, too many nurses with too few physicians, or vice versa, may not produce high-quality care. This suggests that more work is needed to understand staffing mix relative to patient groups, acuity, and the ultimate impact on quality. As Blegen, Goode, and Reed (1998) note, the relationship between nurse staffing levels and quality may, in fact, be convex, rather than linear, and nurse staffing levels may reach a point where too many nurses actually contribute to a decrease in the quality of care. The levels of nurse staffing in this study's sample may be in the range that does not significantly affect quality, leading to inconclusive findings. Differences in the severity of patient illness may not reflect a changing nurse workload. Other unmeasured factors that could influence the nurse workload, such as number of admissions and discharges, may impact the relationship between staffing and adverse events.

Another important issue to note is that HCUP *QIs* are indicators of quality, but they are subject to many sources of errors inherent in administrative or claims data (Iezzoni 1997; Mark and Burleson 1995; Romano and Mark 1994; Silber et al. 1995). There has been a long debate over the reliability, validity, and usefulness of claims/ICD-9-CM as quality measures. Most recently, the research team that developed the Complication Screening Program, which later was integrated into HCUP *QI*, did extensive studies on this issue (Lawthers, McCarthy, and Davis 2000; McCarthy, Iezzoni, and Davis 2000;

Weingart, Iezzoni, and Davis 2000). They concluded: (1) for 13 percent of surgical cases, the conditions identified as complications were judged to be present on admission rather than occurring in-hospital; (2) that 19 percent of surgical-related complications lacked any documented evidence in medical records or physician notes; and (3) physician reviews confirmed that 68.4 percent of cases flagged with complications had substandard care.

Government regulation of RN staffing levels in acute-care hospitals is currently a major health policy issue, with California being the first state to pass legislation mandating staffing levels (Kovner 2000). The Joint Commission on Accreditation of Healthcare Organizations plans to test the effectiveness of staffing strategies and monitoring systems in acute care hospitals with targeted implementation in 2002, perhaps in an effort to stall such government regulation in other states (Greater New York Hospital Association 2001).

This study adds to the increasing body of literature (Buerhaus and Needleman 2000) that supports a relationship between RN staffing levels and adverse events. However, this study does not clearly put the issue to rest. Although this study provides information about mean staffing levels, the optimal level of nurse staffing needed to produce high-quality, cost-effective patient care remains largely unknown. More accurate and consistent measures of acuity and quality, and more complete data on nurse staffing across all levels of nursing staff are needed in future studies to more clearly explain the complex relationship between nurse staffing and quality of care. In the meantime, policy makers and hospital administrators can add the findings from this study to their experience, public opinion, and the reports of stakeholders—including nurses and patients—as data upon which to base decision making on this very important issue.

NOTES

1. We looked at a measure of severity called RDSCALE, which is a later development of the Disease Staging System (Gonnella, Hornbrook, and Louis, 1984; Coffey and Goldfarb 1986; Christofferson, Conklin, and Gonnella, 1988) by Medstat, Inc. RDSCALE values were aggregated at the hospital level for three years (1994–1996) and compared with CMI. Based on the finding that RDSCALE and CMI are highly correlated ($r = .9$), and also out of concern that ICD-9-CM codes used to identify RDSCALE are used to identify adverse events, we chose to use Medicare CMI.
2. These results are available upon request from Dr. Kovner.

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